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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<p>(21) International Application Number: PCT/US00/02873</p> <p>(22) International Filing Date: 4 February 2000 (04.02.00)</p> <p>(30) Priority Data: 60/118,795 5 February 1999 (05.02.99) US</p> <p>(71) Applicant: ROCHESTER INSTITUTE OF TECHNOLOGY [US/US]; 5 Lomb Memorial Drive, Rochester, NY 14623-5603 (US).</p> <p>(72) Inventor: SMITH, Bruce, W.; 558 Ridge Road, Webster, NY 14580 (US).</p> <p>(74) Agents: LEINBERG, Gunnar, G. et al.; Nixon Peabody LLP, Clinton Square, P.O. Box 1051, Rochester, NY 14603 (US).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p><b>Published</b> <i>With international search report.</i></p>	
<p>(54) Title: MASKS FOR USE IN OPTICAL LITHOGRAPHY BELOW 180 NM</p> <p>(57) Abstract</p> <p>A mask for use on a layer of imaging material which is located on at least a portion of one surface of a substrate in a lithography process in accordance with one embodiment of the present invention includes a layer of a masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness of less than about 1000 angstroms. Materials, such as tungsten and amorphous silicon, can be used for the mask.</p>			

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## MASKS FOR USE IN OPTICAL LITHOGRAPHY BELOW 180 NM

This application claims the benefit of U.S. Provisional Patent Application  
5 Serial No. 60/118,795 filed on February 5, 1999 which is herein incorporated by  
reference.

### FIELD OF THE INVENTION

This invention relates generally to lithography and, more particularly, to  
10 masks for use in optical lithography at or below about 180 nm.

### BACKGROUND OF THE INVENTION

Lithography is a process for producing a pattern on a semiconductor wafer.  
The pattern is produced by first exposing a pattern etched into a mask onto a  
15 semiconductor wafer coated with a resist material. The projected image of the pattern  
changes the composition of the resist material on the semiconductor wafer which is  
then removed to leave a matching pattern on the semiconductor wafer for further  
processing.  
20 Depending upon the particular lithography application, the mask needs to  
satisfy several different requirements. The challenge is in finding a material or  
materials for use as the mask which will satisfy these requirements.

Historically, optical masking has been performed using a layer of chromium  
25 rich chromium nitride over fused silica, overcoated with a chromium oxinitride anti-  
reflective ("AR") layer to reduce reflectivity below 10%. Chromium ("Cr") is an  
excellent choice from optical and thermomechanical standpoints at wavelengths  
where it is sufficiently opaque, i.e. wavelengths generally above 180 nm. The spectra  
of chromium metal shown in Figure 1 illustrates why it has been such a good mask  
30 from about 193 nm to about 436 nm. Referring to Figure 2, the optical density  
(plotted here at log (transmission)) of a 1000 Å Cr metal film is shown. Again for

- 2 -

wavelengths between about 193 nm and 500 nm, chromium is an excellent choice. The optical density of Cr film is near 5.0 in the ultraviolet ("UV") range and it decreases to ~4.5 at 193 nm. As thinner Cr metal films are used in manufacturing (800 Å for instance), the optical density above 190 nm may still be sufficiently high  
5 (above 4.0).

However, as shown in Figure 1, chromium metal is a less desirable choice as a mask for wavelengths below 193 nm. Additionally, as shown in Figure 2, at 157 nm, the optical density of the Cr metal film is 3.5 for a 1000 Å film and as low as 3.0 for a  
10 800 Å film. At these optical densities, mask modulation is likely too be low for imaging of fine feature geometry. Unfortunately, a masking film thickness of over about 800 Å is undesirable for 157 nm applications because of the aspect ratio requirements of features smaller than 300 nm. Accordingly, it appears that chromium mask materials may not be adequate below 193 nm, in particular at potential vacuum  
15 ultraviolet ("VUV") wavelengths, i.e. from about 120 nm to 180 nm, such as 157 nm.

Another factor in selecting a mask for use in optical lithography below 180 nm is the etch characteristics of the mask. The mask must have suitable etch characteristics with selectivity to the underlying substrate and to the resist material.  
20 In other words, the film on the substrate which forms the mask must be made of a material or materials which can be etched to form the pattern to be replicated on semiconductor wafers without significant loss to the underlying substrate or to the resist material.

25 As yet, an appropriate replacement material or materials for chromium films for use as the mask for lithography at or below 180 nm, i.e. a mask with the desired optical properties and etch characteristics, has not been found.

#### SUMMARY OF THE INVENTION

30 A mask for use on a layer of imaging material which is located on at least a portion of one surface of a substrate in a lithography process in accordance with one

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embodiment of the present invention includes a layer of a masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms. Materials, such as tungsten and amorphous silicon, can be used for the mask.

5

A lithography system in accordance with another embodiment of the present invention includes a substrate with at least one surface, a layer of imaging material on at least a portion of the one surface, and a layer of masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms on at least a portion of the layer of imaging material.

10

A method for lithography in accordance with another embodiment of the present invention includes a few steps. First, a mask is applied over at least a portion of one surface of a substrate, wherein the mask has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms. Next, a layer of imaging material is applied over at least a portion of the mask. Next, at least a portion of the layer of imaging material and the mask are etched and then the remaining portion of the layer of imaging material is removed.

15

20 The mask is then exposed to radiation at wavelengths at or below about 180 nm.

25

The present invention provides a number of advantages including providing a mask for which has desirable optical properties for use in optical lithography at or below about 180 nm. More specifically, the mask has an optical density of at least 4.0 for wavelengths at or below about 180 nm with a thickness equal to or less than about 1000 angstroms.

30

The present invention also provides a mask with suitable etch characteristics. The layer of masking material can be etched without a significant loss of the underlying substrate or resist material.

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### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph illustrating the absorption coefficient (1/cm) for various metals at wavelengths from 110 nm to 500 nm;

5       Figure 2 is a graph illustrating the optical density of a 1000 Å Cr metal film at wavelengths from 110 nm to 500 nm;

Figure 3 is a graph illustrating the optical density of a 800 Å W film at wavelengths from 110 nm to 500 nm;

10      Figure 4 is a graph illustrating the reflectivity of a 800 Å W film at wavelengths from 110 nm to 500 nm;

Figure 5 is a graph illustrating the reflectivity of an AR coated W film as a function of AR extinction coefficient and thickness;

Figure 6 is a graph illustrating the reflectivity of a 800 Å W film with an AR layer at wavelengths from about 150 nm to 500 nm;

15      Figure 7 is a graph illustrating the absorption coefficient (1/cm) for tungsten, amorphous silicon, and chromium at wavelengths from about 150 nm to 500 nm;

Figure 8 is a graph illustrating the optical density of a 900 Å a-Si film at wavelengths from about 150 nm to 500 nm;

20      Figure 9 is a graph illustrating the reflectivity of a 900 Å a-Si film with an AR layer at wavelengths from about 150 nm to 500 nm; and

Figure 10 is a cross-sectional view of a substrate with a layer of photoresist and a mask in accordance with one embodiment of the invention.

### DETAILED DESCRIPTION

25      A mask film 10 for use in optical lithography at or below about 180 nm in accordance with one embodiment of the invention is illustrated in FIG. 10. The mask 10 has an optical density of at least about 4.0 for wavelengths at or below about 180 nm and a thickness of about 1000 angstroms or less. The present invention provides a number of advantages including providing a mask 10 which has suitable

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optical properties for lithography at or below about 180 nm and has suitable etch characteristics.

Referring to Figure 1, the absorption coefficients (1/cm) for molybdenum 5 (Mo), tungsten (W), chromium (Cr), niobium (Nb), nickel (Ni), tantalum (Ta), and titanium (Ti) metals at wavelengths from 110 nm to 500 nm are illustrated. As discussed in greater detail earlier in the background with reference to Figures 1 and 2, chromium is a good choice for use as a mask 10 for wavelengths ranging between about 193 nm to about 436 nm, but does not possess desirable optical properties as a 10 mask 10 for wavelengths below about 193 nm.

Preferably, a material or materials for use as a mask 10 in optical lithography for wavelengths at or below 180 nm will have an optical density of at least 4.0 for wavelengths at or below 180 nm, conduct sufficient to prevent charging, have dry 15 etch stability, have radiation stability, have good adhesion properties, and have chemical durability. Additionally, the material or materials used for the mask 10 preferably have a thickness equal to or less than about 1000 angstroms, although the thickness can vary as needed or desired.

One example of a material which meets these requirements and is suitable for 20 use as a mask 10 for optical lithography at or below about 180 nm is tungsten. As shown in Figure 1, at about 157 nm tungsten has an absorption coefficient six times that of chromium. Additionally, as shown in Figure 3, an 800 Å thick film of tungsten produces an optical density of 5.0 at about 157 nm which is close to the value for the optical density of chromium at ultraviolet ("UV") wavelengths, i.e. 25 wavelengths between about 250 nm and 450 nm, where chromium is a desired material for a mask 10. Further as shown in Figure 4, the reflectivity of tungsten at 157 mn is near 50%, which can be reduced through use of an anti-reflective layer ("AR") 12. Preferably, a mask 10 made of tungsten has a thickness between about 30 400 Å and 1000 Å, although the thickness can vary as needed or desired.

Another example of a material which is suitable for use as a mask 10 for optical lithography at or below about 180 nm is amorphous silicon. As shown in Figure 7, at about 157 nm amorphous silicon has an absorption coefficient which is 5 1.5 times that of chromium. Although amorphous silicon is not as good a material for a mask 10 as tungsten, it still is acceptable. As shown in Figure 8 a film of amorphous silicon having a thickness of about 900 Å has an optical density near 5.0 at about 157 nm. Preferably, a mask made of amorphous silicon has a thickness between about 400 Å and 1000 Å, although the thickness can vary as needed or 10 desired. Although tungsten and amorphous silicon are disclosed as materials which can be used for the mask 10 for optical lithography at or below about 180 nm, other materials which have an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms may also be used.

15

Preferably, the mask 10 has a reflectivity of less than about 20%, however even if the reflectivity is higher than desired the reflectivity can be reduced. To reduce reflectivity of the mask 10, an optional an AR layer 12, such as a metal nitride, oxide, or fluoride, may be added over at least a portion of the mask 10. Referring to 20 Figure 5, a plot of the reflectivity tungsten as a function of a tungsten nitride, tungsten oxide, or tungsten exintride AR layer 12 extinction coefficient and thickness for a fixed refractive index (real) of 2.7 is shown. As shown in this graph, several possibilities exist that produce a reflectivity below about 10%. Referring to Figure 6, the reflectivity of a film of tungsten with an AR layer 12 of 60 Å is illustrated. As 25 shown in this graph, the reflectivity of the tungsten with the AR layer 12 of 60 Å at about 157 nm is below 10%. Referring to Figure 9, the reflectivity of a film of the layer of amorphous silicon with a silicon oxinitride AR layer 12 of 80 Å is illustrated. As shown in this graph, the reflectivity of the layer of amorphous silicon with the AR layer 12 of 80 Å at about 157 nm is also below 10%. Although tungsten oxinitride 30 and silicon oxinitride are shown as possible AR layers, other materials, such as other

group IV, V, and VI metal nitrides, oxides, and oxinitrides can also be used as AR layers.

Preferably, the material or materials used for the mask 10 in optical 5 lithography for wavelengths at or below 180 nm will have suitable etch characteristics. Both tungsten and amorphous silicon can be easily etched using one of a variety of different etching techniques, such as the use of halogen chemistry, which is well known to those of ordinary skill in the art. Etch rates for both tungsten and amorphous silicon, as well as for any optional AR layers 12, are higher than that 10 demonstrated for chromium.

A lithographic process using a mask 10 in accordance with one embodiment of the present invention will be discussed with reference to Figure 10.

15 First a mask layer 10 is placed over at least a portion of one surface of substrate 16. Preferably, the mask 10 has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms. By way of example only, the mask 10 may comprise a layer of material, such as tungsten or amorphous silicon.

20 Next, an optional AR layer 12 may be added over the mask 10. The AR layer 12 is added to reduce the reflectivity to be preferably below about 20%, although the desired percentage of reflectivity can vary as needed or desired. By way of example only, the AR layer 12 may comprise a layer of material, such as 25 tungsten oxinitride or silicon oxinitride.

Next, a layer of imaging material 14, such as a photoresist, is applied over the mask 10 and the optional AR layer 12. Once the imaging material is in place, the imaging material is exposed and developed using electronic beam or radiation 30 exposure. Next, the mask 10 and the optional AR layer 12 are etched to form the

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desired pattern. A variety of different techniques can be used to etch the mask 10 and the AR layer 12, such as using halogen chemistries, which are well known to those of ordinary skill in the art and thus will not be described here.

- 5 Once the mask 10 the AR layer 12 have been etched into the desired pattern,  
the imaging material 14 is removed.

Having thus described the basic concept of the invention, it will be rather apparent to those skilled in the art that the foregoing detailed disclosure is intended to be presented by way of example only, and is not limiting. Various alternations, improvements, and modifications will occur and are intended to those skilled in the art, though not expressly stated herein. These alterations, improvements, and modifications are intended to be suggested hereby, and are within the spirit and scope of the invention. Accordingly, the invention is limited only by the following claims and equivalents thereto.

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## CLAIMS

### What is claimed is:

1. A mask for use on a layer of imaging material which is located on at least a portion of one surface of a substrate in a lithography process, the mask comprising a layer of a masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms.
- 10 2. The mask as set forth in claim 1 wherein the layer of masking material comprises tungsten.
3. The mask as set forth in claim 2 wherein the tungsten has a thickness between about 400 angstroms and 1000 angstroms.
- 15 4. The mask as set forth in claim 1 wherein the layer of masking material comprises amorphous silicon.
5. The mask as set forth in claim 4 wherein the amorphous silicon has a thickness between about 400 angstroms and 1000 angstroms.
- 20 6. The mask as set forth in claim 1 further comprising an anti-reflective layer over at least a portion of the mask.
- 25 7. The mask as set forth in claim 6 wherein the anti-reflective layer comprises a nitride, oxide, fluoride, or oxinitride of Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W, Cu, Ni, or Fe.
- 30 8. A lithography system comprising:  
a substrate with at least one surface;

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a layer of imaging material on at least a portion of the one surface; and  
a layer of masking material which has an optical density of at least 4.0  
for wavelengths at or below about 180 nm and a thickness equal to or less than about  
1000 angstroms on at least a portion of the layer of imaging material.

5

9. The system as set forth in claim 8 wherein the layer of masking  
material comprises tungsten.

10. The system as set forth in claim 9 wherein the tungsten has a thickness  
10 between about 400 angstroms and 1000 angstroms.

11. The system as set forth in claim 8 wherein the layer of masking  
material comprises amorphous silicon.

15 12. The system as set forth in claim 11 wherein the amorphous silicon has  
a thickness between about 400 angstroms and 1000 angstroms.

13. The system as set forth in claim 8 wherein the layer of imaging  
material comprises photoresist.

20

14. The system as set forth in claim 6 further comprising an anti-reflective  
layer over at least a portion of the mask.

25 15. The system as set forth in claim 14 wherein the anti-reflective layer  
comprises a nitride, oxide, fluoride, or oxinitride of Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W,  
Cu, Ni, or Fe.

16. A method for lithography comprising:

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- placing a mask over at least a portion of one surface of a substrate, wherein the mask has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness of less than about 1000 angstroms;
- 5 applying a layer of imaging material over at least a portion of the mask;
- etching at least a portion of the layer of imaging material and the mask;
- removing the remaining portion of the layer of imaging material; and exposing the mask to radiation at wavelengths at or below about
- 10 180 nm.

17. The method as set forth in claim 16 wherein the mask comprises tungsten.

15 18. The method as set forth in claim 17 wherein the tungsten has a thickness between about 400 angstroms and 1000 angstroms.

19. The method as set forth in claim 16 wherein the mask comprises amorphous silicon.

20 20. The method as set forth in claim 19 wherein the amorphous silicon has a thickness between about 400 angstroms and 1000 angstroms.

25 21. The method as set forth in claim 16 further comprising applying an anti-reflective layer over at least a portion of the mask.

22. The method as set forth in claim 14 wherein the anti-reflective layer comprises a nitride, oxide, fluoride, or oxinitride of Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W, Cu, Ni, or Fe.

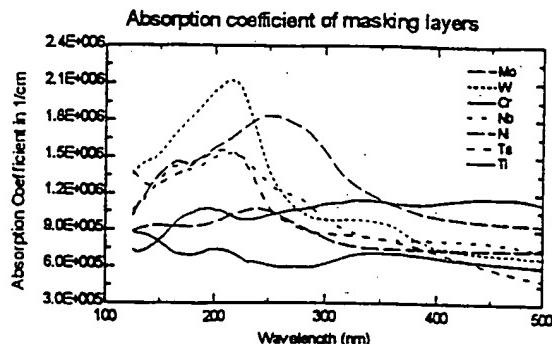


Figure 1

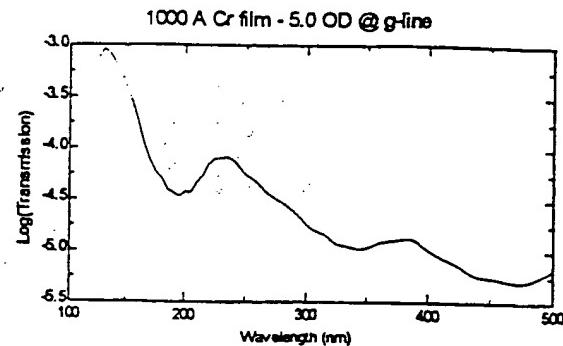


Figure 2

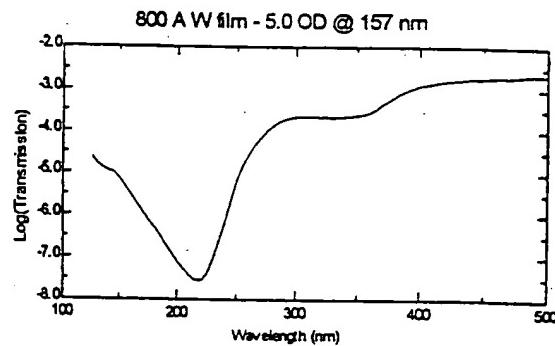


Figure 3

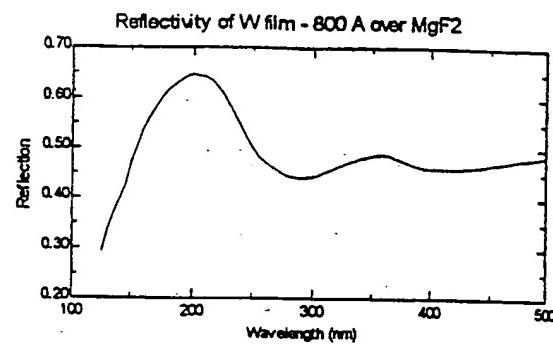


Figure 4

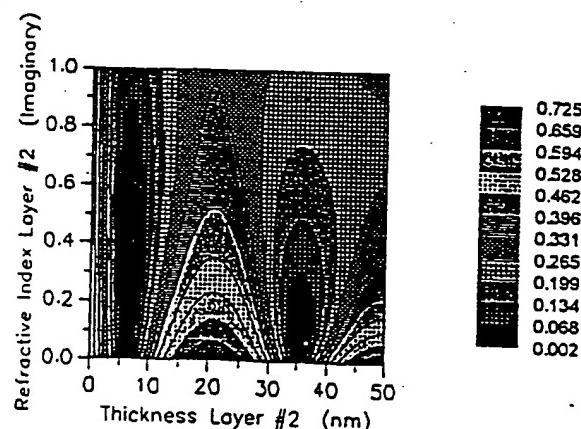


Figure 5

Reflectivity of an AR coated W film as a function of  
AR extinction coefficient and thickness ( $n=2.7$ )

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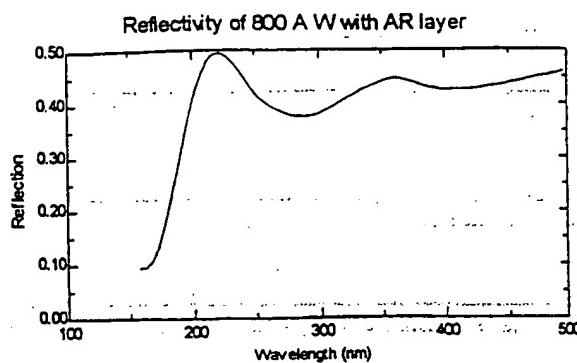


Figure 6

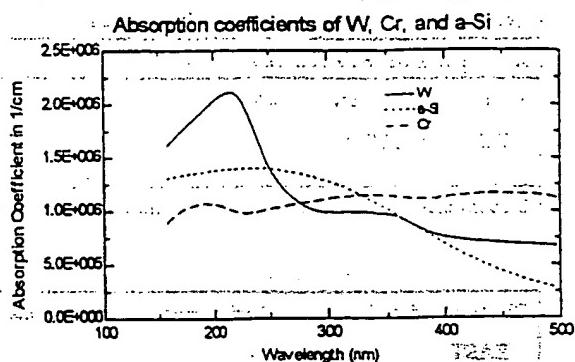


Figure 7

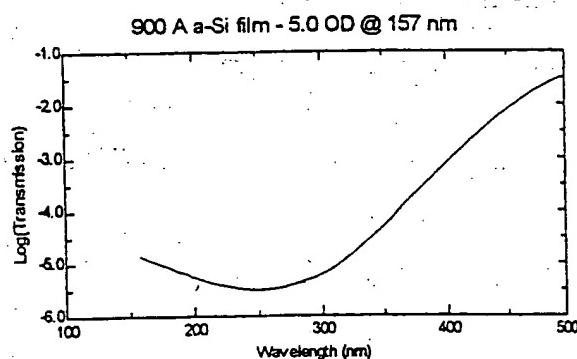


Figure 8

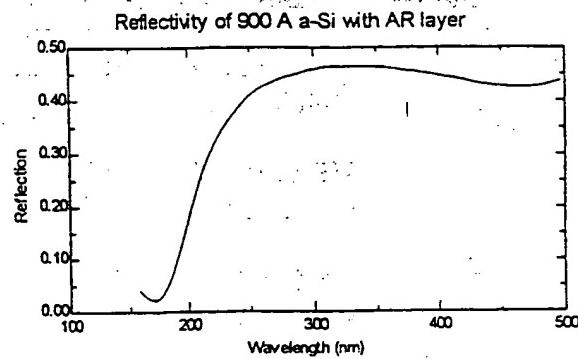


Figure 9

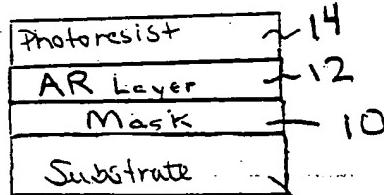


Figure 10

**A. CLASSIFICATION OF SUBJECT MATTER**

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US CL : 430/5

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 430/5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,963,841 A (KARLSSON et al.) 05 October 1999; col. 2, lines 40-45.	6, 14, 21
Y	US 6,040,892 A (PIERRAT) 21 March 2000; col. 3, lines 30-50; col. 3, lines 60-65.	1, 8, 16
Y	US 5,679,484 A (ITO et al.) 21 October 1997; col. 17, lines 40-45; col. 18, lines 30-50.	1, 4-8, 11-16, 19-22
Y	US 6,027,815A (HSU) 22 February 2000; Abstract; col. 5, lines 1-25; col. 6, line 5-25.	1-3, 6, 8-10, 13-14, 16-18, 21
Y	US 5,962,174 A (PIERRAT) 05 October 1999; col. 4, lines 60-65.	1, 8, 16

 Further documents are listed in the continuation of Box C.  See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
23 MARCH 2000	06 APR 2000

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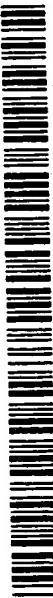
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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.



WO 00/46643 A1

(54) Title: MASKS FOR USE IN OPTICAL LITHOGRAPHY BELOW 180 NM

(57) Abstract: A mask for use on a layer of imaging material which is located on at least a portion of one surface of a substrate in a lithography process in accordance with one embodiment of the present invention includes a layer of a masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness of less than about 1000 angstroms. Materials, such as tungsten and amorphous silicon, can be used for the mask.

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## MASKS FOR USE IN OPTICAL LITHOGRAPHY BELOW 180 NM

This application claims the benefit of U.S. Provisional Patent Application  
5 Serial No. 60/118,795 filed on February 5, 1999 which is herein incorporated by  
reference.

### FIELD OF THE INVENTION

This invention relates generally to lithography and, more particularly, to  
10 masks for use in optical lithography at or below about 180 nm.

### BACKGROUND OF THE INVENTION

Lithography is a process for producing a pattern on a semiconductor wafer.  
The pattern is produced by first exposing a pattern etched into a mask onto a  
15 semiconductor wafer coated with a resist material. The projected image of the pattern  
changes the composition of the resist material on the semiconductor wafer which is  
then removed to leave a matching pattern on the semiconductor wafer for further  
processing.

20 Depending upon the particular lithography application, the mask needs to  
satisfy several different requirements. The challenge is in finding a material or  
materials for use as the mask which will satisfy these requirements.

Historically, optical masking has been performed using a layer of chromium  
25 rich chromium nitride over fused silica, overcoated with a chromium oxinitride anti-  
reflective ("AR") layer to reduce reflectivity below 10%. Chromium ("Cr") is an  
excellent choice from optical and thermomechanical standpoints at wavelengths  
where it is sufficiently opaque, i.e. wavelengths generally above 180 nm. The spectra  
of chromium metal shown in Figure 1 illustrates why it has been such a good mask  
30 from about 193 nm to about 436 nm. Referring to Figure 2, the optical density  
(plotted here at log (transmission)) of a 1000 Å Cr metal film is shown. Again for

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wavelengths between about 193 nm and 500 nm, chromium is an excellent choice. The optical density of Cr film is near 5.0 in the ultraviolet ("UV") range and it decreases to ~4.5 at 193 nm. As thinner Cr metal films are used in manufacturing (800 Å for instance), the optical density above 190 nm may still be sufficiently high 5 (above 4.0).

However, as shown in Figure 1, chromium metal is a less desirable choice as a mask for wavelengths below 193 nm. Additionally, as shown in Figure 2, at 157 nm, the optical density of the Cr metal film is 3.5 for a 1000 Å film and as low as 3.0 for a 10 800 Å film. At these optical densities, mask modulation is likely too be low for imaging of fine feature geometry. Unfortunately, a masking film thickness of over about 800 Å is undesirable for 157 nm applications because of the aspect ratio requirements of features smaller than 300 nm. Accordingly, it appears that chromium mask materials may not be adequate below 193 nm, in particular at potential vacuum 15 ultraviolet ("VUV") wavelengths, i.e. from about 120 nm to 180 nm, such as 157 nm.

Another factor in selecting a mask for use in optical lithography below 180 nm is the etch characteristics of the mask. The mask must have suitable etch characteristics with selectivity to the underlying substrate and to the resist material. 20 In other words, the film on the substrate which forms the mask must be made of a material or materials which can be etched to form the pattern to be replicated on semiconductor wafers without significant loss to the underlying substrate or to the resist material.

As yet, an appropriate replacement material or materials for chromium films 25 for use as the mask for lithography at or below 180 nm, i.e. a mask with the desired optical properties and etch characteristics, has not been found.

## SUMMARY OF THE INVENTION

A mask for use on a layer of imaging material which is located on at least a 30 portion of one surface of a substrate in a lithography process in accordance with one

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embodiment of the present invention includes a layer of a masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms. Materials, such as tungsten and amorphous silicon, can be used for the mask.

5

A lithography system in accordance with another embodiment of the present invention includes a substrate with at least one surface, a layer of imaging material on at least a portion of the one surface, and a layer of masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms on at least a portion of the layer of imaging material.

10 A method for lithography in accordance with another embodiment of the present invention includes a few steps. First, a mask is applied over at least a portion of one surface of a substrate, wherein the mask has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 15 1000 angstroms. Next, a layer of imaging material is applied over at least a portion of the mask. Next, at least a portion of the layer of imaging material and the mask are etched and then the remaining portion of the layer of imaging material is removed.

20 The mask is then exposed to radiation at wavelengths at or below about 180 nm.

The present invention provides a number of advantages including providing a mask for which has desirable optical properties for use in optical lithography at or below about 180 nm. More specifically, the mask has an optical density of at least 25 4.0 for wavelengths at or below about 180 nm with a thickness equal to or less than about 1000 angstroms.

The present invention also provides a mask with suitable etch characteristics. The layer of masking material can be etched without a significant loss of the 30 underlying substrate or resist material.

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### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph illustrating the absorption coefficient (1/cm) for various metals at wavelengths from 110 nm to 500 nm;

5 Figure 2 is a graph illustrating the optical density of a 1000 Å Cr metal film at wavelengths from 110 nm to 500 nm;

Figure 3 is a graph illustrating the optical density of a 800 Å W film at wavelengths from 110 nm to 500 nm;

10 Figure 4 is a graph illustrating the reflectivity of a 800 Å W film at wavelengths from 110 nm to 500 nm;

Figure 5 is a graph illustrating the reflectivity of an AR coated W film as a function of AR extinction coefficient and thickness;

Figure 6 is a graph illustrating the reflectivity of a 800 Å W film with an AR layer at wavelengths from about 150 nm to 500 nm;

15 Figure 7 is a graph illustrating the absorption coefficient (1/cm) for tungsten, amorphous silicon, and chromium at wavelengths from about 150 nm to 500 nm;

Figure 8 is a graph illustrating the optical density of a 900 Å a-Si film at wavelengths from about 150 nm to 500 nm;

20 Figure 9 is a graph illustrating the reflectivity of a 900 Å a-Si film with an AR layer at wavelengths from about 150 nm to 500 nm; and

Figure 10 is a cross-sectional view of a substrate with a layer of photoresist and a mask in accordance with one embodiment of the invention.

### DETAILED DESCRIPTION

25 A mask film 10 for use in optical lithography at or below about 180 nm in accordance with one embodiment of the invention is illustrated in FIG. 10. The mask 10 has an optical density of at least about 4.0 for wavelengths at or below about 180 nm and a thickness of about 1000 angstroms or less. The present invention provides a number of advantages including providing a mask 10 which has suitable

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optical properties for lithography at or below about 180 nm and has suitable etch characteristics.

Referring to Figure 1, the absorption coefficients (1/cm) for molybdenum  
5 (Mo), tungsten (W), chromium (Cr), niobium (Nb), nickel (Ni), tantalum (Ta), and titanium (Ti) metals at wavelengths from 110 nm to 500 nm are illustrated. As discussed in greater detail earlier in the background with reference to Figures 1 and 2, chromium is a good choice for use as a mask 10 for wavelengths ranging between about 193 nm to about 436 nm, but does not possess desirable optical properties as a  
10 mask 10 for wavelengths below about 193 nm.

Preferably, a material or materials for use as a mask 10 in optical lithography for wavelengths at or below 180 nm will have an optical density of at least 4.0 for wavelengths at or below 180 nm, conduct sufficient to prevent charging, have dry  
15 etch stability, have radiation stability, have good adhesion properties, and have chemical durability. Additionally, the material or materials used for the mask 10 preferably have a thickness equal to or less than about 1000 angstroms, although the thickness can vary as needed or desired.

One example of a material which meets these requirements and is suitable for use as a mask 10 for optical lithography at or below about 180 nm is tungsten. As shown in Figure 1, at about 157 nm tungsten has an absorption coefficient six times that of chromium. Additionally, as shown in Figure 3, an 800 Å thick film of tungsten produces an optical density of 5.0 at about 157 nm which is close to the value for the optical density of chromium at ultraviolet ("UV") wavelengths, i.e.  
25 wavelengths between about 250 nm and 450 nm, where chromium is a desired material for a mask 10. Further as shown in Figure 4, the reflectivity of tungsten at 157 mn is near 50%, which can be reduced through use of an anti-reflective layer ("AR") 12. Preferably, a mask 10 made of tungsten has a thickness between about  
30 400 Å and 1000 Å, although the thickness can vary as needed or desired.

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Another example of a material which is suitable for use as a mask 10 for optical lithography at or below about 180 nm is amorphous silicon. As shown in Figure 7, at about 157 nm amorphous silicon has an absorption coefficient which is 5 1.5 times that of chromium. Although amorphous silicon is not as good a material for a mask 10 as tungsten, it still is acceptable. As shown in Figure 8 a film of amorphous silicon having a thickness of about 900 Å has an optical density near 5.0 at about 157 nm. Preferably, a mask made of amorphous silicon has a thickness between about 400 Å and 1000 Å, although the thickness can vary as needed or 10 desired. Although tungsten and amorphous silicon are disclosed as materials which can be used for the mask 10 for optical lithography at or below about 180 nm, other materials which have an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms may also be used.

15 Preferably, the mask 10 has a reflectivity of less than about 20%, however even if the reflectivity is higher than desired the reflectivity can be reduced. To reduce reflectivity of the mask 10, an optional an AR layer 12, such as a metal nitride, oxide, or fluoride, may be added over at least a portion of the mask 10. Referring to 20 Figure 5, a plot of the reflectivity tungsten as a function of a tungsten nitride, tungsten oxide, or tungsten exinitride AR layer 12 extinction coefficient and thickness for a fixed refractive index (real) of 2.7 is shown. As shown in this graph, several possibilities exist that produce a reflectivity below about 10%. Referring to Figure 6, the reflectivity of a film of tungsten with an AR layer 12 of 60 Å is illustrated. As 25 shown in this graph, the reflectivity of the tungsten with the AR layer 12 of 60 Å at about 157 nm is below 10%. Referring to Figure 9, the reflectivity of a film of the layer of amorphous silicon with a silicon oxinitride AR layer 12 of 80 Å is illustrated. As shown in this graph, the reflectivity of the layer of amorphous silicon with the AR layer 12 of 80 Å at about 157 nm is also below 10%. Although tungsten oxinitride 30 and silicon oxinitride are shown as possible AR layers, other materials, such as other

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group IV, V, and VI metal nitrides, oxides, and oxinitrides can also be used as AR layers.

Preferably, the material or materials used for the mask 10 in optical  
5 lithography for wavelengths at or below 180 nm will have suitable etch characteristics. Both tungsten and amorphous silicon can be easily etched using one of a variety of different etching techniques, such as the use of halogen chemistry, which is well known to those of ordinary skill in the art. Etch rates for both tungsten and amorphous silicon, as well as for any optional AR layers 12, are higher than that  
10 demonstrated for chromium.

A lithographic process using a mask 10 in accordance with one embodiment of the present invention will be discussed with reference to Figure 10.

15 First a mask layer 10 is placed over at least a portion of one surface of substrate 16. Preferably, the mask 10 has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms. By way of example only, the mask 10 may comprise a layer of material, such as tungsten or amorphous silicon.

20 Next, an optional AR layer 12 may be added over the mask 10. The AR layer 12 is added to reduce the reflectivity to be preferably below about 20%, although the desired percentage of reflectivity can vary as needed or desired. By way of example only, the AR layer 12 may comprise a layer of material, such as  
25 tungsten oxinitride or silicon oxinitride.

Next, a layer of imaging material 14, such as a photoresist, is applied over the mask 10 and the optional AR layer 12. Once the imaging material is in place, the imaging material is exposed and developed using electronic beam or radiation exposure. Next, the mask 10 and the optional AR layer 12 are etched to form the  
30

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desired pattern. A variety of different techniques can be used to etch the mask 10 and the AR layer 12, such as using halogen chemistries, which are well known to those of ordinary skill in the art and thus will not be described here.

5 Once the mask 10 and the AR layer 12 have been etched into the desired pattern, the imaging material 14 is removed.

Having thus described the basic concept of the invention, it will be rather apparent to those skilled in the art that the foregoing detailed disclosure is intended to 10 be presented by way of example only, and is not limiting. Various alterations, improvements, and modifications will occur and are intended to those skilled in the art, though not expressly stated herein. These alterations, improvements, and modifications are intended to be suggested hereby, and are within the spirit and scope of the invention. Accordingly, the invention is limited only by the following claims 15 and equivalents thereto.

**CLAIMS****What is claimed is:**

1. A mask for use on a layer of imaging material which is located on at least a portion of one surface of a substrate in a lithography process, the mask comprising a layer of a masking material which has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness equal to or less than about 1000 angstroms.
- 10 2. The mask as set forth in claim 1 wherein the layer of masking material comprises tungsten.
- 15 3. The mask as set forth in claim 2 wherein the tungsten has a thickness between about 400 angstroms and 1000 angstroms.
4. The mask as set forth in claim 1 wherein the layer of masking material comprises amorphous silicon.
- 20 5. The mask as set forth in claim 4 wherein the amorphous silicon has a thickness between about 400 angstroms and 1000 angstroms.
6. The mask as set forth in claim 1 further comprising an anti-reflective layer over at least a portion of the mask.
- 25 7. The mask as set forth in claim 6 wherein the anti-reflective layer comprises a nitride, oxide, fluoride, or oxinitride of Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W, Cu, Ni, or Fe.
- 30 8. A lithography system comprising:  
a substrate with at least one surface;

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a layer of imaging material on at least a portion of the one surface; and  
a layer of masking material which has an optical density of at least 4.0  
for wavelengths at or below about 180 nm and a thickness equal to or less than about  
1000 angstroms on at least a portion of the layer of imaging material.

5

9. The system as set forth in claim 8 wherein the layer of masking  
material comprises tungsten.

10. The system as set forth in claim 9 wherein the tungsten has a thickness  
10 between about 400 angstroms and 1000 angstroms.

11. The system as set forth in claim 8 wherein the layer of masking  
material comprises amorphous silicon.

15 12. The system as set forth in claim 11 wherein the amorphous silicon has  
a thickness between about 400 angstroms and 1000 angstroms.

13. The system as set forth in claim 8 wherein the layer of imaging  
material comprises photoresist.

20

14. The system as set forth in claim 6 further comprising an anti-reflective  
layer over at least a portion of the mask.

25 15. The system as set forth in claim 14 wherein the anti-reflective layer  
comprises a nitride, oxide, fluoride, or oxinitride of Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W,  
Cu, Ni, or Fe.

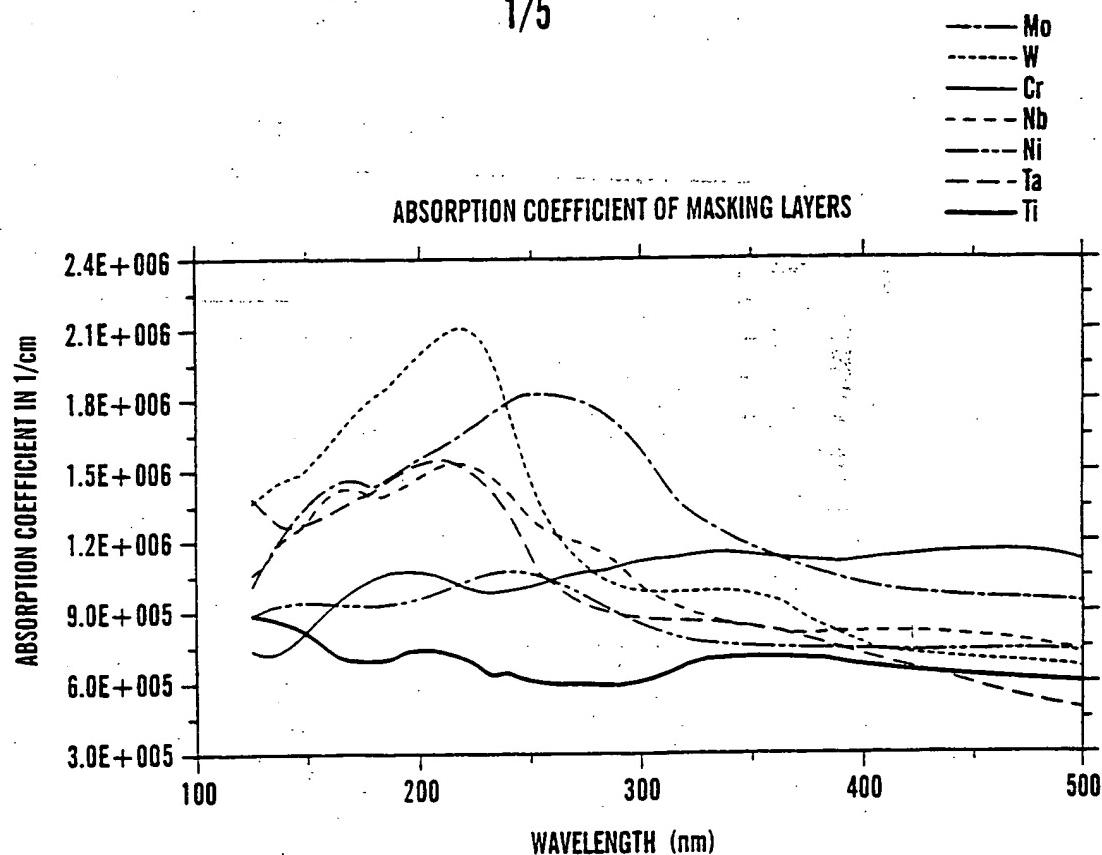
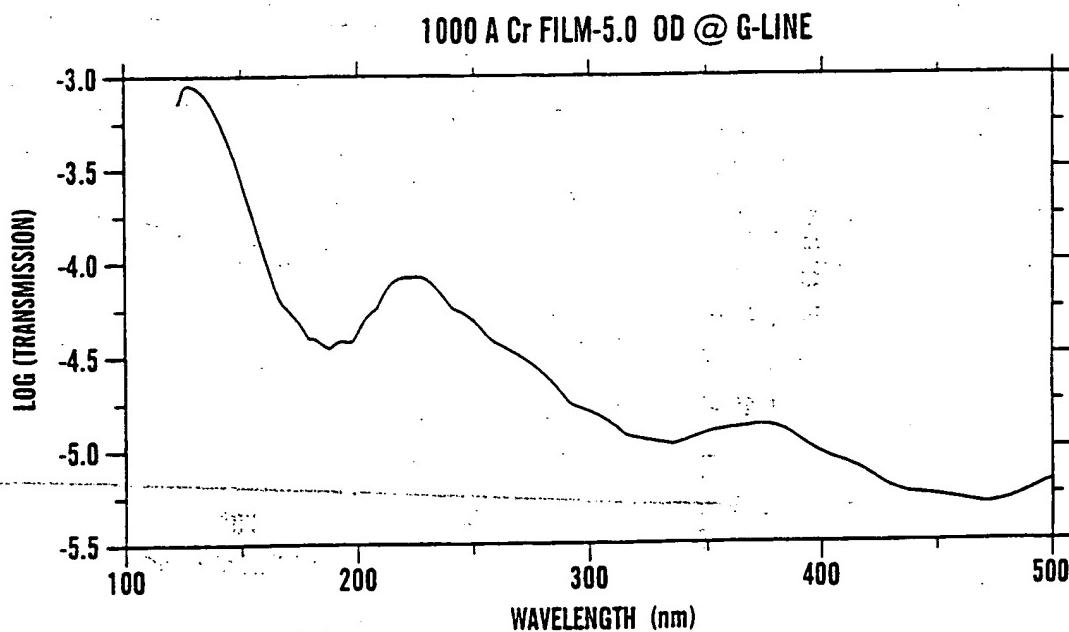
16. A method for lithography comprising:

- 11 -

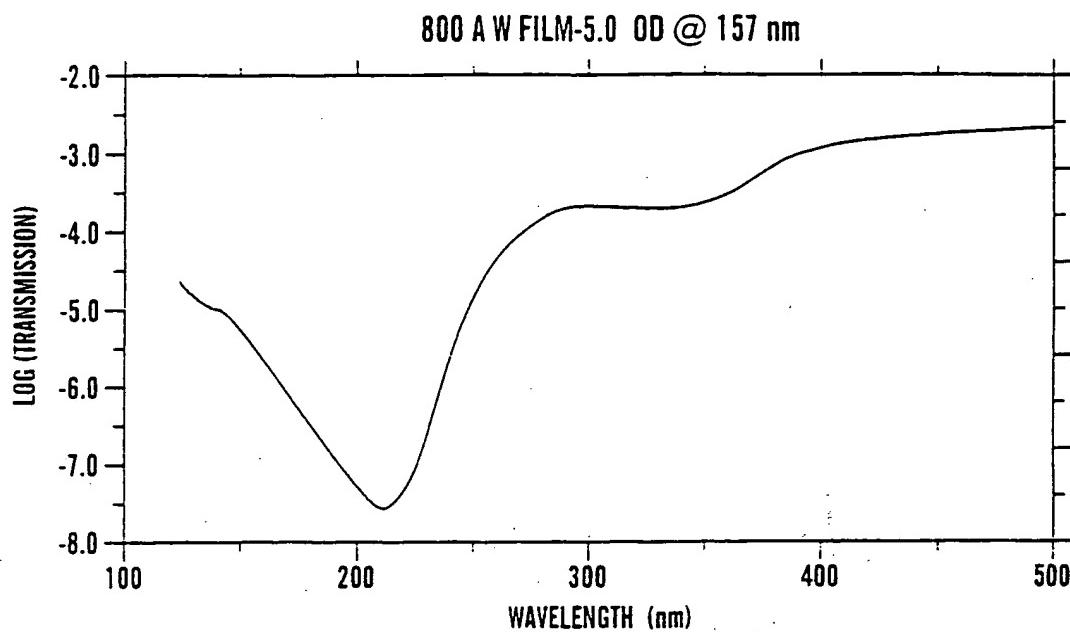
- placing a mask over at least a portion of one surface of a substrate, wherein the mask has an optical density of at least 4.0 for wavelengths at or below about 180 nm and a thickness of less than about 1000 angstroms;
- 5 applying a layer of imaging material over at least a portion of the mask;
- etching at least a portion of the layer of imaging material and the mask;
- removing the remaining portion of the layer of imaging material; and exposing the mask to radiation at wavelengths at or below about
- 10 180 nm.
17. The method as set forth in claim 16 wherein the mask comprises tungsten.
- 15 18. The method as set forth in claim 17 wherein the tungsten has a thickness between about 400 angstroms and 1000 angstroms.
19. The method as set forth in claim 16 wherein the mask comprises amorphous silicon.
- 20 20. The method as set forth in claim 19 wherein the amorphous silicon has a thickness between about 400 angstroms and 1000 angstroms.

21. The method as set forth in claim 16 further comprising applying an anti-reflective layer over at least a portion of the mask.
- 25 22. The method as set forth in claim 14 wherein the anti-reflective layer comprises a nitride, oxide, fluoride, or oxinitride of Ti, V, Cr, Zr, Nb, Mo, Hf, Ta, W, Cu, Ni, or Fe.

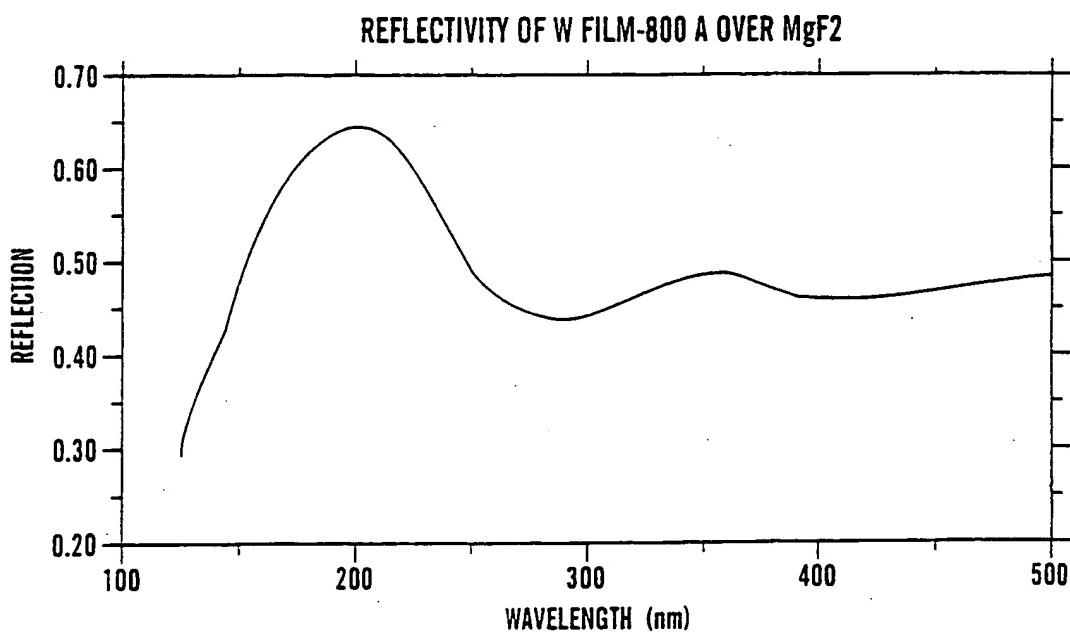
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**FIG. 1****FIG. 2**

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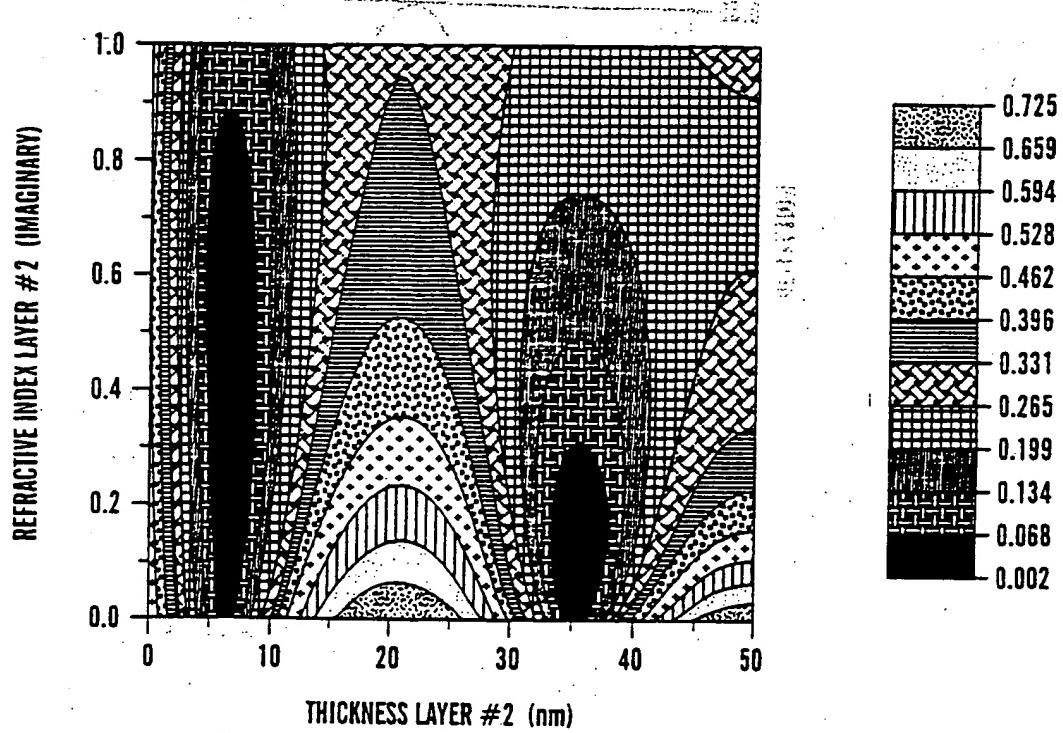
**FIG. 3**



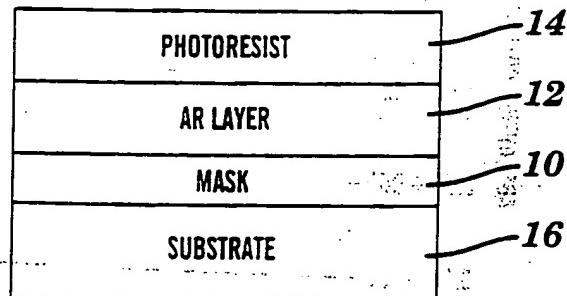
**FIG. 4**

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**REFLECTIVITY OF AN AR COATED W FILM AS A FUNCTION OF  
AR EXTINCTION COEFFICIENT AND THICKNESS ( $n=2.7$ )**



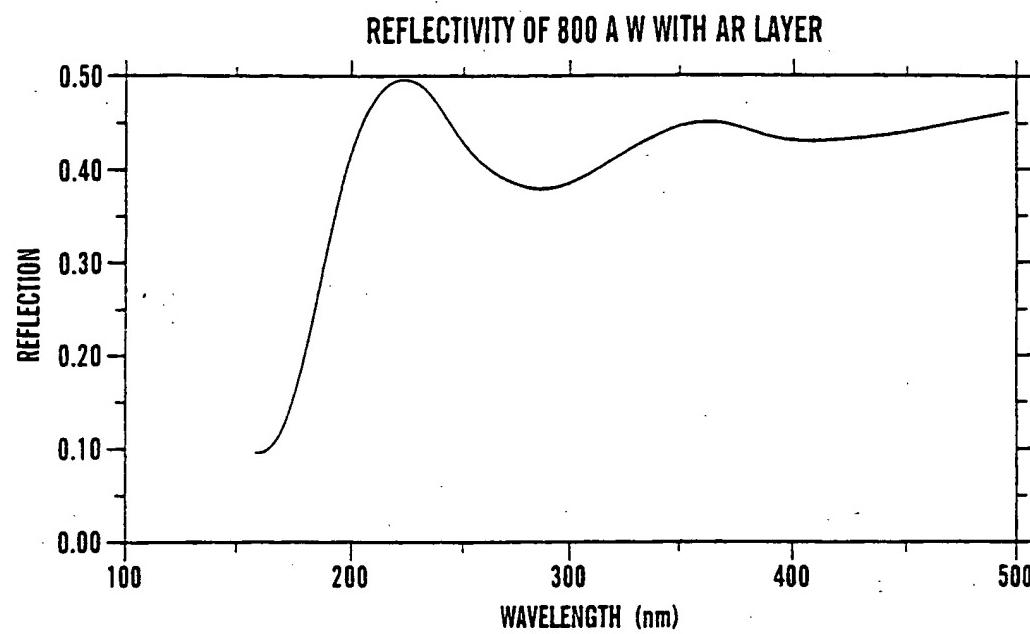
**FIG. 5**



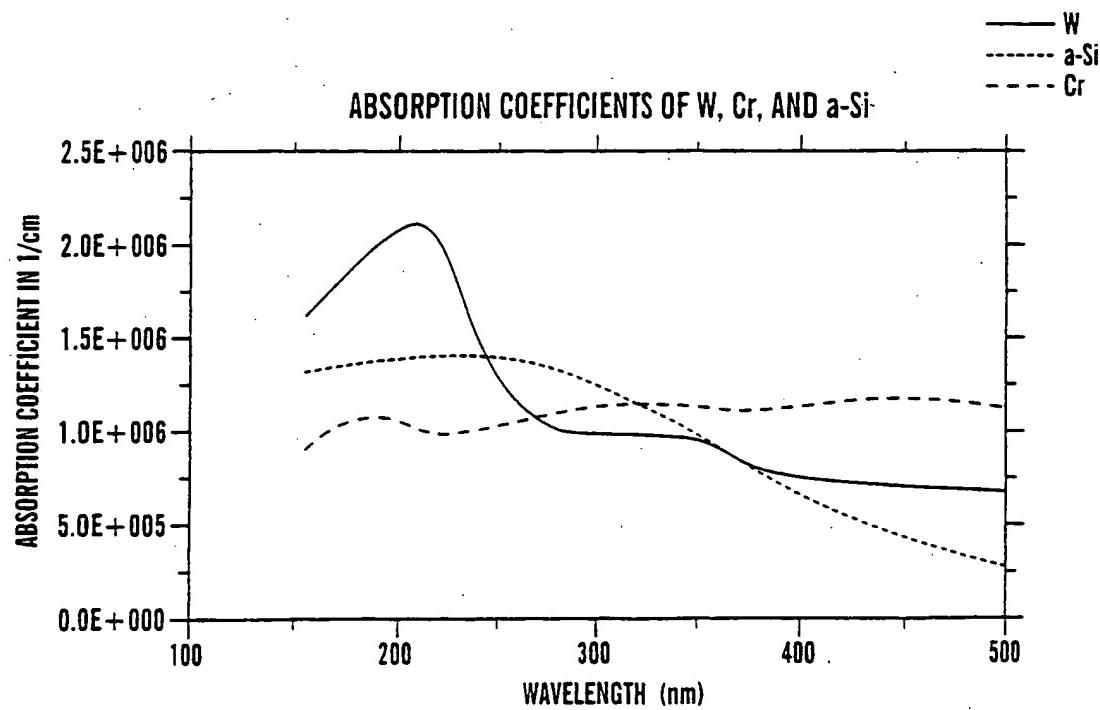
**FIG. 10**

**SUBSTITUTE SHEET (RULE 26)**

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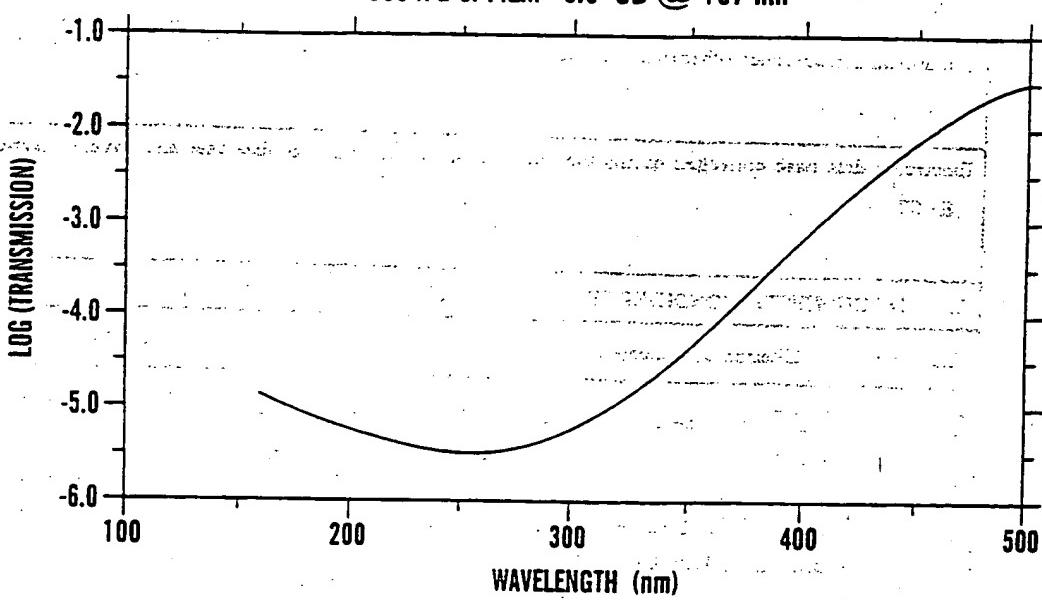
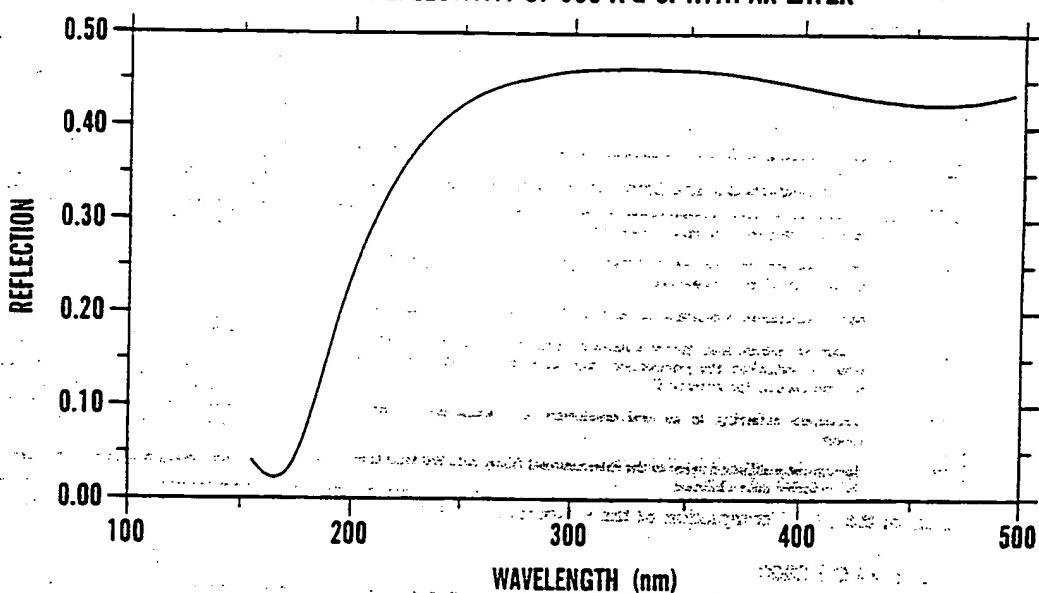


**FIG. 6**



**FIG. 7**

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**900 A a-Si FILM - 5.0 OD @ 157 nm****FIG. 8****REFLECTIVITY OF 900 A a-Si WITH AR LAYER****FIG. 9****SUBSTITUTE SHEET (RULE 26)**

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G03F 9/00

US CL : 430/5

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 430/5

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EAST

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,963,841 A (KARLSSON et al.) 05 October 1999; col. 2, lines 40-45.	6, 14, 21
Y	US 6,040,892 A (PIERRAT) 21 March 2000; col. 3, lines 30-50; col. 3, lines 60-65.	1, 8, 16
Y	US 5,679,484 A (ITTO et al.) 21 October 1997; col. 17, lines 40-45; col. 18, lines 30-50.	1, 4-8, 11-16, 19-22
Y	US 6,027,815A (HSU) 22 February 2000; Abstract; col. 5, lines 1-25; col. 6, line 5-25.	1-3, 6, 8-10, 13-14, 16-18, 21
Y	US 5,962,174 A (PIERRAT) 05 October 1999; col. 4, lines 60-65.	1, 8, 16

 Further documents are listed in the continuation of Box C. See patent family annex.

• Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
• "A" document defining the general state of the art which is not considered to be of particular relevance	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
• "B" earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
• "L" document which may throw doubt on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Z"	document member of the same patent family
• "O" document referring to an oral disclosure, use, exhibition or other means		
• "P" document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search

23 MARCH 2000

Date of mailing of the international search report

06 APR 2000

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